2. Meet Your Neighbours

Lying on the continental shelf, the Salish Sea is a labyrinth of remarkable coastal waterways. From shallow embayments to deep fjords, rocky reefs and soft river deltas, these waters provide countless places for marine plants and animals to live. When these geographic features are combined with varying amounts of sunlight, salt and oxygen, the food web for thousands of animal species is created, a food web so rich that it supported the world's smallest and largest creatures for millennia.

Marine Mammals

Twenty-seven species of marine mammals have been observed in the Salish Sea. Thirteen of them can be found regularly. For these animals, the Salish Sea serves a multitude of purposes—feeding, breeding, resting, overwintering, or simply as a migratory corridor. Some species, such as killer whales and Pacific white-sided dolphins, range widely, but others, such as sea otters, are more closely associated with specific areas.

Steller Sea Lions: Voracious Salmon Predators?
In the 1900's, the belief that sea lions "competed" with humans for salmon led to the slaughter of entire breeding rookeries. More than 55,000 Steller sea lions in BC were killed. We now know that salmon are a relatively small proportion (around 10%) of the sea lion's diet (Heise et al. 2003).

PHOTO: J. HILDERING

A Troubled Past

Our recent history with marine mammals in the Salish Sea does not summon pride. From the early 1700s to the 1970s, humans have managed to reduce most of the Salish Sea marine mammals to a fraction of their previous numbers.

Starting with the fur trade, sea otters were extirpated[1] from the province in a quest for fur and wealth. The elephant seal, chosen because of its abundant stores of oil, was next to be hunted to near collapse. As the value of oil increased, a new and easier target was identified in grey whales, which were hunted to

1 A local extinction; a species (or other taxon) ceases to exist in a specific geographic area, though it still exists elsewhere.

PHOTO: BC ARCHIVES

commercial extinction by the late 1800s. The newfound power of steam and steel then accelerated the killing of larger, faster whales, and with this, the populations of minke and humpbacks disappeared from the Salish Sea and other coastal waters (Nichol et al. 2002).

Even the most ubiquitous of marine mammals, the harbour seal, showed a dramatic population decline by the 1960s as a result of more than 500,000 being killed for bounties, commercial hunting, and predator control measures.

Perhaps the most grievous atrocity committed against the marine mammals of the Salish Sea was the live capture of killer whales prior to 1974 for the aquarium trade. Forty-eight (48) individuals from the southern resident population and five transient killer whales were taken from their family units or

NAME	COMMON NAME	NATIONAL CONSERVATION STATUS
Phoca vitulina	Harbour seal	NOT AT RISK
Mirounga angustirostris	Northern elephant seal	NOT AT RISK
Eumetopias jubatus	Steller sea lion	SPECIAL CONCERN (COSEWIC 2003a, SARA)
Zalophus californianus	California sea lion	NOT AT RISK
Enhydra lutris	Sea otter	SPECIAL CONCERN (COSEWIC 2007, SARA)
Phocoena phocoena	Harbour porpoise	SPECIAL CONCERN (COSEWIC 2003b, SARA)
Lagenorhynchus obliquidens	Pacific white-sided dolphin	NOT AT RISK
Phocoenoides dalli	Dall's porpoise	NOT AT RISK
Orcinus orca	Southern resident killer whale	ENDANGERED (COSEWIC 1998, SARA 2003)
	Biggs (Transient) killer whale	THREATENED (COSEWIC 2008, SARA)
Eschrichtius robustus	Grey whale	SPECIAL CONCERN (COSEWIC 2004, SARA)
Balaenoptera acutorostrata	Minke whale	NOT AT RISK
Balaenoptera noveangliae	Humpback whale	SPECIAL CONCERN (COSEWIC 2011a); THREATENED (SARA)

Table 2.1: Common marine mammals of the Salish Sea and their corresponding conservation status according to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Species at Risk Act (SARA)

died in the capture process (Olesiuk et al. 1990). The removal of these animals caused biological and cultural devastation among the remaining pod members and intense suffering to those sentenced to life in captivity.

Because marine mammals reproduce slowly and invest great care in a single offspring, many are vulnerable to over-exploitation and other human related threats. Consequently, recovery from significant population reductions can take many years. The encouraging prospect is that ending destructive human behaviours can stabilize and reverse populations in decline.

A Remarkable Sighting
Driven to virtual extinction in BC during the height of whaling, the North Pacific right whale has made an astonishing reappearance. Following 60 years without a sighting, two right whales have been spotted off the BC coast, one just outside of the Juan de Fuca Strait. These sightings (shown on map) have brought new hope that this once fated species could return.

PHOTO: J. FORD, FISHERIES AND OCEANS CANADA

Figure 2.2 Location of recent North Pacific Right Whale sightings.

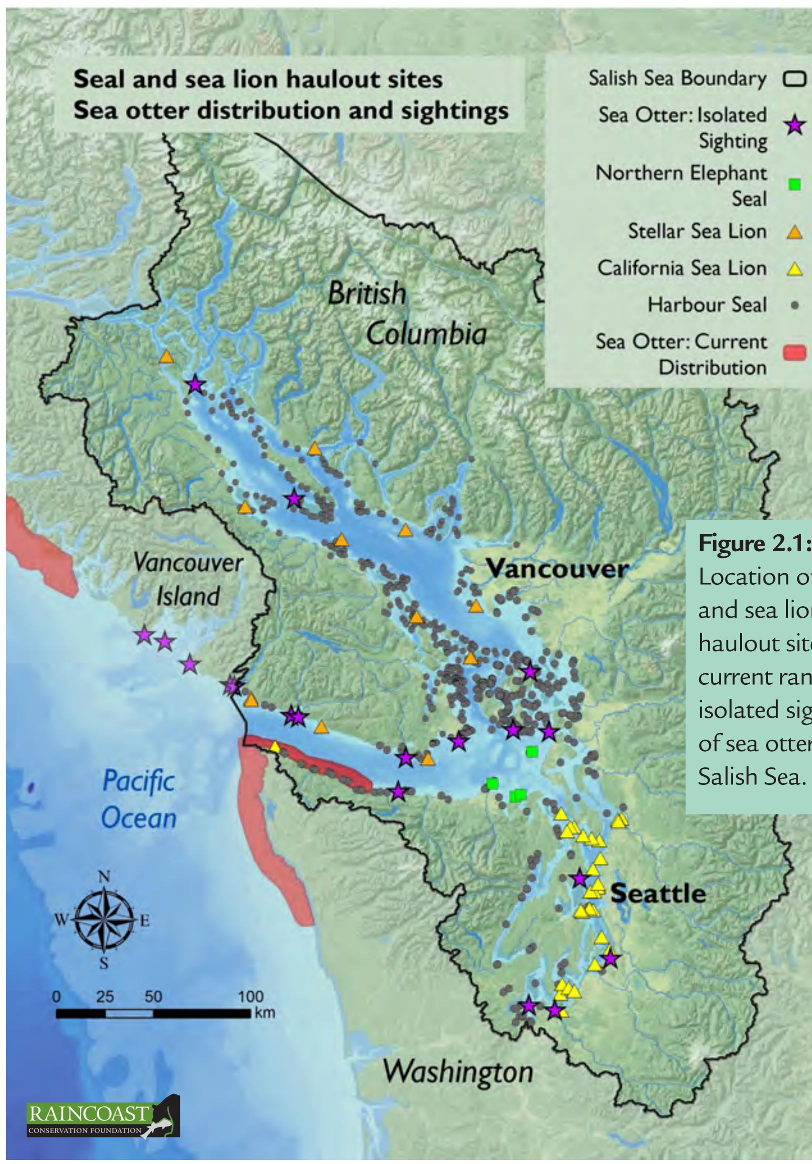


Figure 2.1: Location of seal and sea lion haulout sites with current range and isolated sightings of sea otters in the Salish Sea.

The Road to Recovery

Many marine mammal populations of the Salish Sea are slowly recovering. Areas uninhabited in recent history are gradually being recolonized and large aggregations of marine mammals are now being seen. Some species, however, show little sign of recovery and their future remains uncertain. This is particularly true for the Southern Resident killer whales.

Fur Bearers

Northern Elephant Seal

The recent presence of elephant seal pups at Race Rocks in the Strait of Juan de Fuca suggests this to be a new—and most northern—breeding site for elephant seals.

PHOTO CREDIT: E. BOERNER, NOAA

The northern elephant seal is another species recovering from near extinction. More than 175,000 individuals are now thought to live on North America's west coast (Weber et al. 2000). Elephant seals migrate north from their major breeding rookeries in California and Mexico (Jeffries et al. 2000). Elephant seals are not known to breed in BC, however the presence of pups in the last five years at a (previous) haul-out in the Salish Sea, suggests this is a new—and the most northern—breeding site (Race Rocks 2014).

Steller Sea Lion

Steller Sea Lions
Steller sea lions have no breeding rookeries in the Salish Sea but use 11 known haul-out sites, primarily in the winter.

PHOTO: M.MACDUFFEE

Steller sea lions are one of the most studied marine mammals in the North Pacific. This is because the western population in Alaska (west of 144 ^{0} W) has declined by 80% since the 1970s and is considered endangered in the US. Causes of the decline are the focus of much research and debate. Nutritional stress due to reduced food availability or quality, high predation of pups by transient killer whales (Horning and Mellish 2012), and natural fluctuation have been identified as potential causes.

In Canada, the eastern population of Steller sea lions (east of 1440 W extending down into California) was assessed as Special Concern by SARA in 2003. Hunting and predator culls in the last century killed more than 50,000 sea lions and reduced the population to fewer than 4,000 individuals in three breeding rookeries (Heise et al. 2003, Bigg 1985). Since the culls stopped in 1970, Steller sea lion numbers in BC have increased to between 20,000 and 28,000 (Fisheries 2010a; Fisheries 2008).

California Sea Lion
Often accused of competing for salmon, a sea lion's diet consists more of smaller forage fish, squid, and octopus (Jeffries et al. 2000; Lowry et al. 1991)

PHOTO: T. ORR, NOAA

California Sea Lion

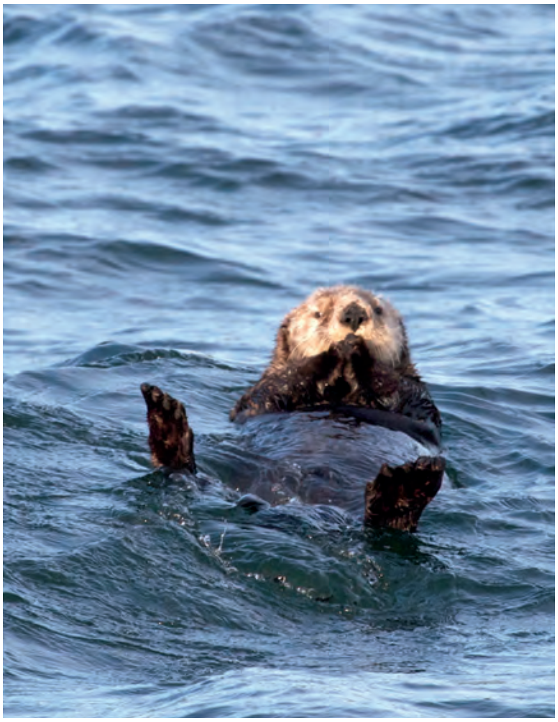
Predominantly a southern species, the California sea lion breeds and lives primarily in California and Mexico. Numbers are estimated at 153,000 individuals (Jeffries et al. 2000; NOAA 2011). Only males seem to migrate northward far enough to reach the Salish Sea and have been observed in spring, summer, and fall (Jeffries et al. 2000; Bigg 1985).

Sea Otter—A Reintroduction Success Story

After being extirpated by commercial hunting, sea otters were reintroduced to British Columbia in an attempt to recolonize historic habitat. Likewise, in the United States, 59 sea otters were reintroduced to the Salish Sea in the 1970s along the coast of Washington. This group now numbers upwards of 1,073 individuals (Jameson and Jeffries 2010) and occupies rocky habitat on the northwest coast of Washington.

Harbour Seals.
Harbour seals that live in harbours and ports are particularly toxic and pose a risk to the whales that eat them (Ross et al. 2004; Ford et al. 2012). Health risks include reproductive impairment, decreased immune function, increased incidence of disease, skeletal abnormalities, and neurological impairment (Fisheries 2007a).

PHOTO; J. FITZ-HIRSCHBOLD



Sea Otter
Healthy kelp beds are one benefit from the reintroduction of sea otters to Washington State, as their consumption of urchins reduces over grazing on kelp (Lance et al. 2004).

PHOTO: M. MACDUFFEE

Toothed Whales

Dolphins and Porpoises

The dolphins and porpoises most commonly sighted in the Salish Sea are the harbour porpoise, Dall's porpoise, and Pacific white-sided dolphin. Recent estimates suggest BC's inside waters host between 5,000–10,000 harbour porpoises and Dall's porpoises (each), and about 25,000 Pacific white-sided dolphins (Best et al. 2015). The density and distribution of these small cetaceans can be linked to the local availability small schooling fish, their primary food (Walker et al. 1998; Heise 1997). Entanglement in fishing gear is one of the biggest threats to their survival.

Super Pods in the Salish Sea
Since the mid 1980s, Pacific white-sided dolphins have become increasingly common in BC's inshore waters (Heise 1997), including recent sightings of dolphin super pods in the Salish Sea. These impressive aggregations can contain more than 1,500 individuals.

PHOTO: C. MOTT

Salish Sea Subpopulations are at Greater Risk
Shy harbour porpoises rarely travel in large gregarious groups like their Dall's or Pacific white-sided cousins. BC's harbour porpoise may be split into genetically and geographically distinct units (Chivers et al. 2002). This puts the subpopulations at greater risk from disturbances that would not typically threaten the entire population (Fisheries 2009).

PHOTO: W. CURTZINGER

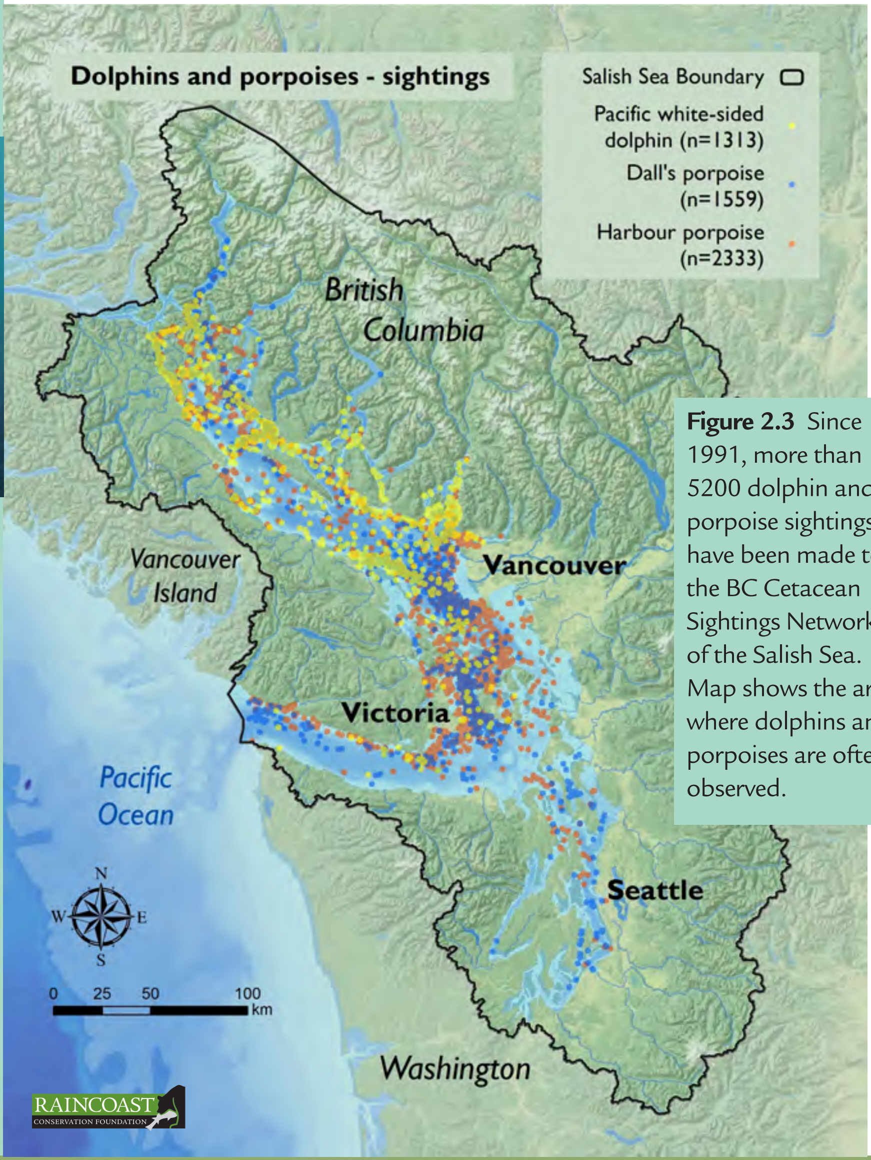


Figure 2.3 Since 1991, more than 5200 dolphin and porpoise sightings have been made to the BC Cetacean Sightings Network of the Salish Sea. Map shows the area where dolphins and porpoises are often observed.

Southern Resident Killer Whales

Perhaps the most revered and iconic species in the Salish Sea, the Southern Resident killer whales, are also the most critically endangered. These salmon-eating whales are genetically distinct from their northern counterparts and have about one-third their numbers. In 2015, the southern resident killer whale population comprised less than 85 individuals, separated into three groups of closely related matrilines known as J, K, and L pods.

Thought to be present sporadically throughout the winter and more consistently during the summer, new research is showing that many whales, particularly J Pod, spend considerable time in the Salish Sea throughout the year (NOAA 2014).

Surrounded on All Sides

The southern residents travel in relatively large groups that vocalize with each other. This makes them easy for researchers and observers to find, but has led to a near constant flotilla of followers. The sound and disturbance from vessel traffic makes finding food and communication more difficult (Lusseau et al. 2009, Williams et al. 2014). Despite the knowledge that decreased food supply, pollutants, increased noise, and habitat disturbance are affecting whale survival, no adequate actions are being taken to address these threats.

85 Southern Resident killer whales eat between 300,000 and 600,000 Chinook salmon a year, depending the percent of Chinook in their diet, the size and age of the whales and the size and age of the Chinook salmon (Ford et al. 2011a).

PHOTO J. TOWERS

Figure 2.4: Almost half of the Salish Sea has been identified by Canadian and US federal governments as critical to the survival of the Southern Resident killer whales. All three pods use their critical habitat (red) and surrounding areas throughout the year.

The Salmon Eaters

The Southern Resident killer whales have a favourite food—Chinook (spring) salmon. In the summer, these whales target Chinook stocks from the Fraser River and Puget Sound (Hanson et al. 2010). The abundance of Chinook salmon is linked to the survival of the resident whales, with nutritional stress causing increased mortality in years of decreased Chinook salmon availability (Ford et al. 2005). Because of the evidence linking Chinook abundance with killer whale vital rates (like birth and death rates; Ford et al. 2005, 2010, Velez-Espino et al. 2014), measures must be taken to ensure killer whales can catch sufficient numbers of Chinook, particularly in years when Chinook abundance is low.

Transient Killer Whales

Although it is hard visually to distinguish between resident killer whales and transient (increasingly called Biggs) killer whales, they differ widely in their diet, behaviour, and range.

Figure 2.5 Proposed critical habitat of transient killer whales in the Salish Sea encompasses the entire BC coastline up to three nautical miles from shore (Ford et al. 2012).

Fire-proof Killer Whales
Transient killer whales that frequent the Salish Sea contain very high levels of toxic pollutants (Ross 2006). Chemicals such as PCBs, flame retardants, and pesticides are introduced from urban and industrial areas to harbours and ports within the Salish Sea.

PHOTO: G. MILLER

More Seals, More Seal Eaters
After receiving protection from commercial hunting and predator control measures that killed more than 500,000 harbour seals by the 1970s, the Salish Sea population has grown from an estimated 4,000 to approximately 40,000 (Olesiuk 1999). The now abundant seal has attracted their primary predator—transient killer whales. In the last 30 years, these mammal-eaters have dramatically increased their numbers and presence in the Salish Sea.

PHOTO: L. JONES, NOAA

These stealthy, silent predators travel in small quiet groups up and down the coast in search of food. They feed exclusively on marine mammals: particularly harbour seals, porpoises, and sea lions. Transient killer whales observed in the Salish Sea belong to the West Coast Transient population, estimated at 250 individuals. They can appear in the Salish Sea throughout the year, but are seen in greater abundance in the late summer when harbour seals have young pups (Ford et al. 2012).

In the last 30 years, the number of transient killer whales observed in the Salish Sea has increased dramatically, from 10 in 1980 to more than 120 in 2010, with an increase from 60 to 120 between 2000 and 2010 alone. The whales are also arriving in larger groups sizes (Ford et al. 2010). This rapid increase corresponds to recovery of harbour seals and other prey within the Salish Sea (Ford et al. 2011b).

Grey whales are often sighted migrating through BC waters in groups of 1-5. Their route takes them into Salish Sea shipping lanes, an area of known ship strike mortality (Douglas et al. 2008).

PHOTO: C. HYSLOP

Stranded Grey Whale
A successful feeding season is the difference between life and death. In 1999, mass strandings and deaths of grey whales were recorded all along their migration route. The deaths were attributed to starvation and a hypothesized decrease in (krill-like) amphipods in bottom sediments of the northern feeding grounds (LeBouef et al. 2000). An estimated 30,000 whales in 1997 dropped to a startling 16,000 in 2001, showing just how destructive natural or human-caused changes to food availability can be (Rugh et al. 2005)

PHOTO: B. STOTESBURY, TIMES COLONIST

Baleen Whales

Grey Whales

Despite a collapse in grey whales to 2,000 individuals after whaling, the eastern population of North Pacific grey whales has recently been estimated at more than 20,000 (Rice et al. 1984; Punt and Wade 2012). Unique among whales, the grey whale is primarily a bottom feeder, which sifts through sediment to obtain amphipods, mysids and other bottom dwelling invertebrates. These whales travel great distances in search of suitable patches of ocean floor on which to feed. The migration between their winter calving grounds in Southern and Baja California to their northern feeding grounds in the Arctic seas is more than 8,000 km (Pike 1962).

Humpback Whales—A Feeding Mission

Humpback whales are typically present in coastal BC from May to October. Our waters, and those in Alaska, are the northern feeding grounds for whales after leaving their winter calving sites in more tropical waters. Abundance in BC's inside waters has been estimated at around 1,500 animals during these months (Best et al. 2015).

During their stay in northern waters, a humpback's objective is feeding. They must sequester enough energy to maintain themselves through the lean winters in southern seas. Areas where high concentrations of food (typically krill, herring, and sardines) attract humpbacks have been proposed as critical habitat. One of these sites is the entrance to Juan de Fuca Strait (Nichol et al. 2009). Humpbacks appear to be particular about their feeding grounds and as such, may be more susceptible to habitat degradation and energy spent looking for food elsewhere (Calambokidis et al. 2001).

Some Whales don't Want to Leave.
Approximately 200 grey whales remain on the BC coast during the summer months, abandoning the long Arctic migration (Calambokidis et al. 2002). This group has been coined the Pacific Coast Feeding Aggregation and are a distinct subpopulation (Frasier et al. 2011).

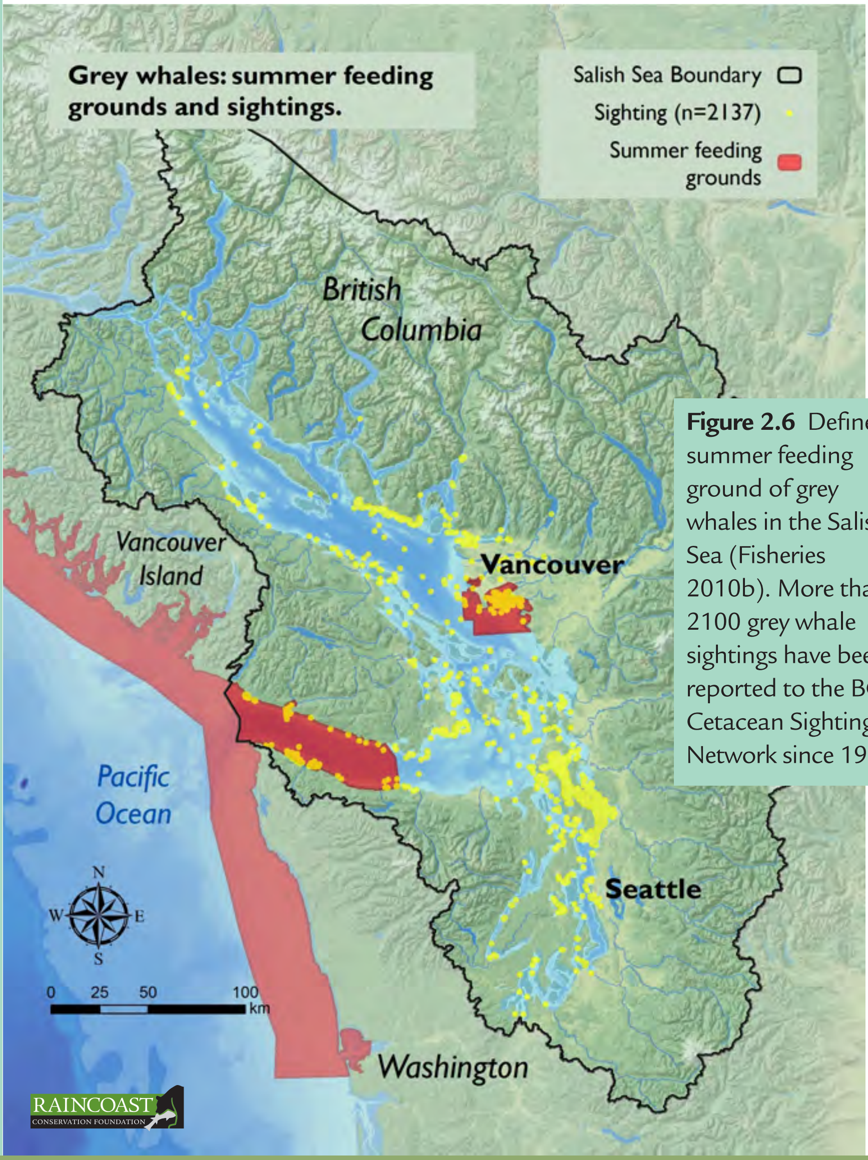


Figure 2.6 Defined summer feeding ground of grey whales in the Salish Sea (Fisheries 2010b). More than 2100 grey whale sightings have been reported to the BC Cetacean Sightings Network since 1988

Minke Whales—The Elusive Loner

Minke whales are most commonly observed in the Salish Sea in the spring, summer, and fall where they feed on small schooling fish. Their coast wide population is estimated at less than 500 individuals (Best et al. 2015). They are primarily seen alone, or in similar areas but acting independently of one another. As with humpbacks, when Minke's find a good feeding area, they tend to linger (Dorsey et al. 1990).

Whaling in the Strait of Georgia, 1908

Captain Larsen at the harpoon gun on the St. Lawrence in the Strait of Georgia in 1908. A whaling station operated here from October 1907 to February 1908, processing 98 humpback whales before it was closed. In total, more than 24,000 whales were slaughtered as part of BC's commercial whaling efforts.

PHOTO: BC ARCHIVES

Whales: The Ocean's Gardeners

Commercial whaling devastated whale abundance in the southern ocean over the last two centuries. But it wasn't until recently that the decline of whales was linked to the decline in krill and iron concentrations (Lavery et al. 2010). The discovery provides an explanation for how the southern ocean once supported much more life than it can today. Simply put, whales function like an ocean pump that concentrate and return iron to surface waters where it kick-starts marine food webs. See Chapter 3.

PHOTO: H. HUMCHITT

Wings over the Salish Sea

The Salish Sea lies along the path of the Pacific Flyway (figure 2.6), a critical migratory route for millions of marine and terrestrial birds that stretches from South America to the high Arctic. The Salish Sea region provides habitat to more than 170 species of marine birds, offering food, shelter, a place to find mates, socialize, moult, and overwinter (Gaydos and Pearson 2011). Some of these birds are year-round residents and others are visitors as they move around the margins of the Pacific Ocean and beyond.

In addition to marine birds, the Salish Sea watersheds are home to land-based bird species. These lands are a mosaic of coastal habitats, including saltwater marshes, estuaries, fields, and forests that interact with marine waters. Although no exact numbers are available, roughly 130 species of land-based birds inhabit the terrestrial areas bounded within the Salish Sea watersheds.

Globally, marine birds face a litany of direct and indirect threats from humans. Humans degrade or destroy their habitat, hunt them, compete for fish and other food, introduce species they cannot cope with, and pollute their waters with plastics, oil, and other contaminants. Unfortunately, the Salish Sea is no exception. Threats to marine birds include lost or degraded habitat, oil spills of all sizes (O'Hara et al. 2009), contaminants (Calambokidis et al. 1985, Elliot et al. 1996), disturbance (Chatwin 2010), introduced mammals on bird colonies, and fishing. Fishing affects food supply (e.g., herring abundance, Therriault et al. 2009) and causes death from by-catch in nets, long lines (Hamel et al. 2009) and derelict fishing gear (Good et al. 2009).

What is a Marine Bird?

There is no single definition of marine birds. The term marine birds captures true seabirds like puffins, shearwaters, and albatross, but can also include marine-associated birds like waterfowl (ducks, herons, cormorants, gulls), shorebirds (e.g. sandpipers, turnstones) and raptors (e.g. osprey, eagles, and falcons).

Figure 2.6: Pacific Flyway.

CREDIT: U.S. FISH & WILDLIFE SERVICE

Diving Birds, Diving Numbers

Of the marine and marine-associated birds known to occur in the Salish Sea, at least 23 are listed as Species At Risk or are candidates for provincial/state or federal listings (Gaydos and Brown 2009). Further, long-term monitoring of marine birds in the Salish Sea indicates substantial declines in many species, including Western Grebes, Marbled Murrelets, and Common Murres (Anderson et al. 2009 and Bower 2009). Several of these, including Marbled Murrelets, are of urgent conservation concern and declines in the Salish Sea mimic widespread declines elsewhere in their range. For many species, the causes of declining populations remain unresolved.

Marine birds can act as sentinels of ecosystem health (Piatt et al. 2007). Substantial declines are often indicative of trouble for a broader range of plants and animals. Some fish eating birds, such as Western Grebes, have seen dramatic winter declines in the Salish Sea over the last several decades. This disappearance correlates with declining Pacific herring in the Salish Sea and increased sardine abundance off California, where grebe abundance has increased (Wilson et al. 2013).

PHOTO: J.GAYDOS

For the Birds—The Fraser River Delta

At the mouth of the Fraser River lies the largest estuary on Canada's Pacific coast, comprising 754 km^2 near densely populated Vancouver. The Fraser River estuary is of provincial, national, continental and global importance for marine birds.

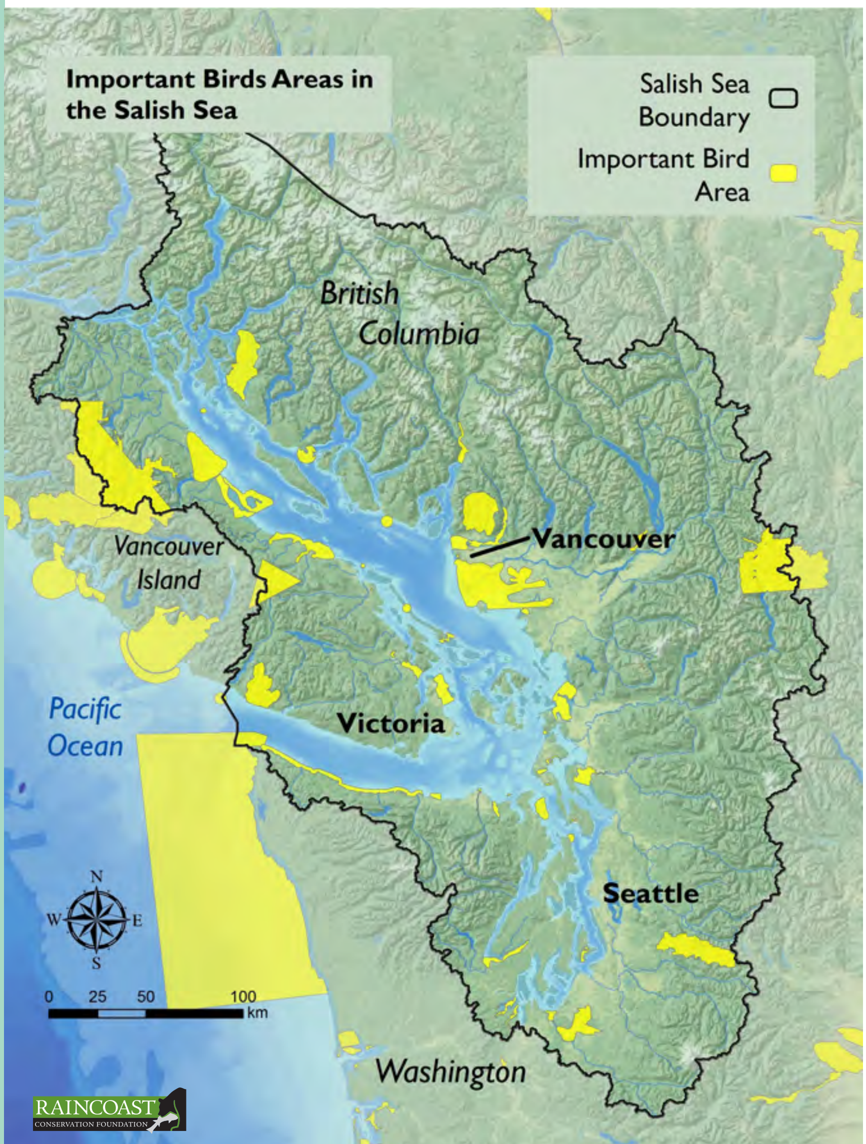


Figure 2.7: Important Bird Areas in Canada (Nature Canada) and in Washington (National Aubudon Society)

Each spring, millions of migratory shorebirds and waterfowl descend onto the Fraser delta to forage, rest, and refuel on their long distance migrations (BC CDC 2006).

In summer, raptors and songbirds are abundant over the fields, hedges, and forests. By late summer, the early trickle of returning migrants from northern breeding grounds increases to a steady flood of millions of birds by fall. During the fall and winter, daily counts of over 100,000 waterfowl are common. Species such as the Western Sandpiper have daily estimates as high as 500,000 (IBA Canada 2015). At times like this, the Fraser delta supports substantial portions of the global populations of some bird species (IBA Canada 2015). While many of these species will continue to move south, for some, such as the Northern Pintails and Brant, the area provides crucial overwintering habitat.

The Fraser River estuary is the largest on Canada's Pacific coast. In addition to its designation as an Important Bird Area, the region contains a Western Hemisphere Shorebird Reserve, a Migratory Bird Sanctuary, the Reifel Bird Sanctuary, and the Alaksen Wildlife Refuge. Supporting millions of birds, the Fraser River delta is of immense importance locally and globally.

PHOTO: E. LESSON

Western Sandpipers in the Fraser River delta have had daily abundance estimates as high as 500,000 during their spring migration. In the last two decades, peak counts have been below 200,000. This still represents a significant percentage of the global Western Sandpiper population (IBA 2015).

PHOTO I. GUTHIE

Fin Fish of the Salish Sea

Five species of commercial salmon (and three species of recreationally fished salmonids) use the rivers, estuaries, and pelagic waters of the Salish Sea. Their habitat extends from the smallest coastal streams to the largest rivers and deltas, the kelp and eel grass beds, the sheltered bays, and the straits leading to and from the North Pacific.

PHOTO: J. KORESKI

Salmon

A *foundation species*[2] of the coastal ecosystem, salmon are one of the most important groups of fish in our waters. They play an incomparable ecological role in marine, freshwater and riparian systems and helped build the rich river valleys that once blanketed the Pacific Northwest (Gende et al. 2002, Schindler et al. 2003). These forested rivers in turn provided the shelter, food, and growing conditions needed to nourish future generations of salmon.

Unfortunately, this remarkable conveyor belt of salmon nutrients and energy to the watersheds and wildlife of western North America has been vastly diminished (through multiple ways) or severed (by dams) throughout much of their historic range (Gresh et al. 2000, Lichatowich 2001, Price et al. 2008, 2013).

A salmon's life entails being both predator and prey. Eating insects initially, their diet changes to zooplankton, larger invertebrates, and often other fish species. In turn, young and adult salmon are also food for more than 130 wildlife species including birds, sharks, dolphins, seals, sea lions, toothed whales, and even other salmon (Cederholm 1999).

The strategy of salmon to leave coastal streams for richer (ocean) pastures and then return to spawn, is a remarkable adaptation that serves both salmon and the ecosystem. Upon their return to coastal streams, salmon are a thousand times larger than when they left, with roughly 3% of their body weight composed of nitrogen and phosphorous (Larkin and Slaney 1997).

Salmon have always faced poor odds for survival. From egg to adult, they are eaten, endure habitat limitations, or do not find food at the right place or time. As such, more than 99% of the eggs a female salmon produces do not survive to become spawning salmon. With such poor odds, it is not hard to tip the balance to declining salmon returns once human activities

PHOTO: A. WRIGHT/COLD-COAST.COM

2 A foundation species is distinct from a *keystone* species. In ecology, the term refers to a species that has a strong role in structuring a community, such as bison or cod. A keystone species has an influence on its surroundings that is disproportionate to its abundance. The influence of salmon is due to their immense abundance and biomass. See Soulé et al. 2003.

are added to the mix. A century of over-fishing, intense urban, agricultural and industrial development in watersheds and on shorelines, the presence of salmon aquaculture net-pens on migration routes, the unintended consequences of hatcheries and the effects of climate change, have pushed many salmon populations that rear in or migrate through the Salish Sea to a fraction of their former numbers (Gresh et al. 2000, Lichatowich 1999, Grant et al. 2011).

Oil tankers, along with the development of other energy and shipping terminals in the Fraser River and Roberts Bank, present a new, added threat to salmon. These threats come from chronic small spills and episodic large spills that degrade and contaminate sensitive shorelines critical to salmon survival. They also come from pavement, roads, shoreline armoring and construction within estuaries, and the extensive loss of vital rearing habitat these activities cause.

Figure 2.8 Salmon conservation units and ecologically significant units of the Salish Sea.

Everyone waits for salmon
Even though returning salmon are focussed on spawning, their arrival is awaited by hungry animals from bears to birds. The food contained in their bodies delivers the energy, fat, and protein that wildlife need before hibernating, migrating, giving birth, or simply surviving the winter (Darimont et al. 2010, Hilderbrand et al. 2004).

The nutrients from spawned and eaten carcasses, and from the excreted waste of wildlife that feed on salmon, break down to become the biochemical building blocks for future forests and forest life.

PHOTO: M.CARWARDINE

The Salish Sea is home to roughly 60 ecologically and/or genetically distinct groups of salmon populations, each one of which is unique and irreplaceable. In Canada, these groups are called Conservation Units (CUs); in the US, they are called Evolutionarily Significant Units (ESUs).

Forage Fish—Linking the Top and Bottom of the Marine Foodweb

Forage fish are the target of the world's largest fisheries, but they play key roles in marine food webs by transferring energy from plankton to upper trophic-level predators, such as large fish, seabirds, and marine mammals (Essington et al. 2015).

Situated loosely between zooplankton and bigger fishes, forage fish are a vital link that connects the bottom and the top of the foodweb (Pikitch et al. 2012). From tiny egg to mature fish, they are a food source that fuels much bigger predators, including salmon, marine mammals, and seabirds.

In the Salish Sea, the group we call 'forage fish' is made up of several species, including eulachon (oo-lig-an), surf smelt, Pacific sand lance, and Pacific herring. Each species has different and complex strategies for life; some spawn on beaches, others use shallow bays or freshwater, or spawn offshore. Some are residents of the Salish Sea while others are migratory, visiting for shorter periods.

The forage fish of BC are also woven into the human and natural history of the coast. They carry immense cultural, social, and economic value to First Nations. One of the best examples is eulachon, also known as candlefish for its ability to be lit like a candle once dried and wicked. A highly valued food item, eulachon oil was once traded inland via 'grease trails', named after the rendered fish grease that dripped out as it was transported. With such large population declines, eulachon now represent a tiny fraction of the Salish Sea's forage fish.

A staggering rate of decline (~98% in 10 years) is a major factor in listing the Fraser River eulachon population as Endangered (COSEWIC 2011).

PHOTO: R. MILLER

Herring Spawning Locations (BC and WA) and Commercial Harvest Areas (BC only)

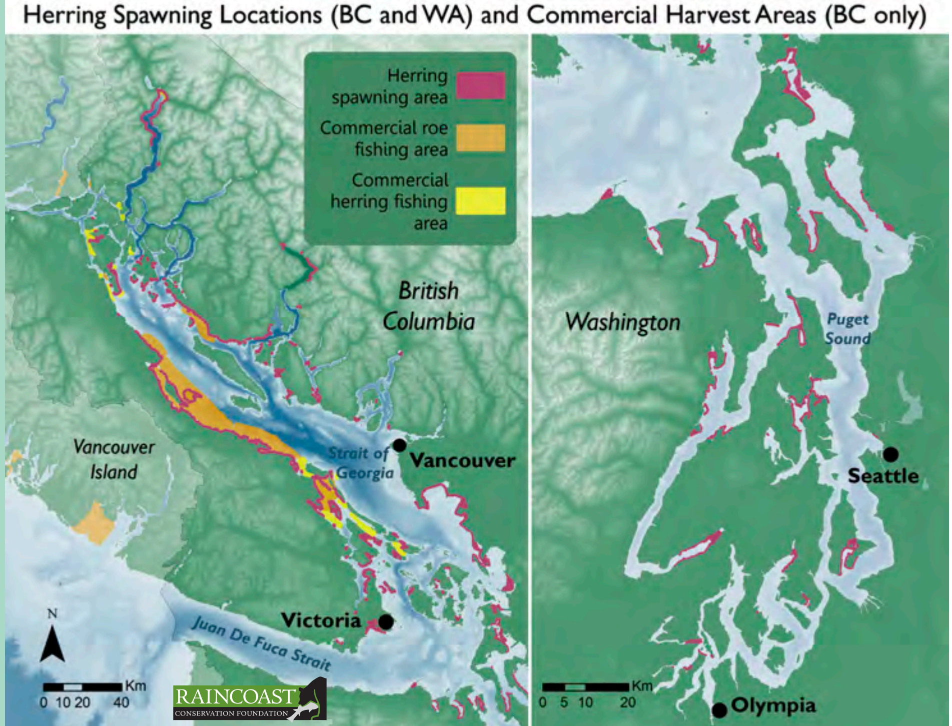


Figure 2.9 Herring spawning locations (Canada and US) and commercial fishery locations (Canada only).

Of the coast's spectacular natural events, the spawning of Pacific herring ranks among the best. Each spring in the Salish Sea, swarms of herring aggregate and spawn. Eastern Vancouver Island is a favoured area, with many contiguous kilometres of intertidal and nearshore subtidal areas experiencing spawn events.

PHOTO: H. SCHULZ

Roughly half of the Strait of Georgia and west coast Vancouver Island Pacific herring biomass is consumed by fish and marine mammals each year (Schweigert et al. 2010). This is a huge transfer of nutrients and energy to surrounding marine life such as salmon, lingcod, seals, dolphins, humpback whales, and countless marine birds. Without herring, many of the Salish Sea's most popular inhabitants would need to find food elsewhere.

PHOTO: G. MAZILLE

The Silver Wave

Beginning in warmer waters in the southern parts of their range, Pacific herring spawn events proceed north along the Pacific coast in a 'silver wave'. At these spawn events, male herring release milt (sperm), which turns the water milky white, often far out to sea. Each female lays as many as 20,000 eggs (Hay 1985) upon eelgrass, kelp and other substrates. At these spawn events, massive aggregations of marine predators show up to feast, including hundreds of thousands of birds, hundreds of sea lions and, depending on the location of the spawn, whales. Foraging for several weeks, the spawning adults and their eggs provide a pulse of fat-rich food at a time (generally early spring in BC) when other resources are low.

Pacific herring are considered BC's dominant forage fish but they, like eulachon, have experienced sharp declines. For several decades in the last century, Pacific herring were the target of the largest commercial fishery in BC, with landed tonnages and values that exceeded even Pacific salmon.

The Strait of Georgia herring fishery remains open, and currently represents the largest herring fishery in BC. Of the remaining four major herring populations in BC, controversy and objection by multiple First Nations has erupted over the decision to open commercial fisheries on three populations, which are slowly rebuilding following years of low abundance. In Puget Sound, less than half the managed 'stocks' are considered healthy (Stick and Lindquist 2009).

Salish Sea Pacific herring are far more important than simply being the target of a commercial fishery. Like salmon, Pacific herring are a foundation species (Soulé et al. 2003) and the dominant forage fish not just in the Salish Sea, but throughout the BC coast (Schweigert et al. 2010). As such, they make substantial contributions to the diets of bigger fish and other animals (Schweigert et al. 2010).

The Ghosts of Past Overfishing

Because herring are a dominant forage fish, fluctuations in their populations ripple throughout marine foodwebs. But concerns for their conservation extend beyond their numbers. Major questions still surround the genetic diversity of herring populations and how they compare with those of the past.

In the Salish Sea, most herring belong to a large population that migrates between summer foraging grounds off the west coast of Vancouver Island and winter spawning grounds in the Salish Sea. However, some resident herring populations stay year round in the Salish Sea (Therriault et al. 2009). Genetically distinct populations have been identified at spawning grounds in Esquimalt, in BC's mainland inlets (Beacham et al. 2008), and at Cherry Point south of Blaine, Washington (Small et al. 2005).

Having previously collapsed and been subject to heavy fishing pressure for more than a century, the health of herring populations both large and small are of conservation concern. Research using archaeological and genetic analyses of ancient herring remains provides promise for evaluating the effects of the commercial fishery on herring diversity and abundance (Speller et al. 2012, McKechnie et al. 2014).

Despite their high ecosystem importance, forage fish are poorly understood. For species with commercial value, such as Pacific herring, we have a basic understanding of their biomass, where they live, feed, and breed. However, other forage fishes such as Pacific sand lance, surf smelt, and longfin smelt, lack even basic information relating to their numbers and where they roam.

This lack of information combines with the history of exploitation and development in the Salish Sea to muddy the waters that would identify causes for their low and declining abundance. In their examination of global forage fisheries, Essington and colleagues (2015) implicate fishing in forage fish stock collapses by showing that high fishing rates are maintained when stock productivity is in rapid decline. In the Salish Sea, many drivers of habitat loss, including damaged intertidal zones, noise, and pollution, act cumulatively to reduce the abundance of forage fish. When Kinder Morgan's expansion project is added to this mix, the concern for forage fish and the species that rely on them is magnified.

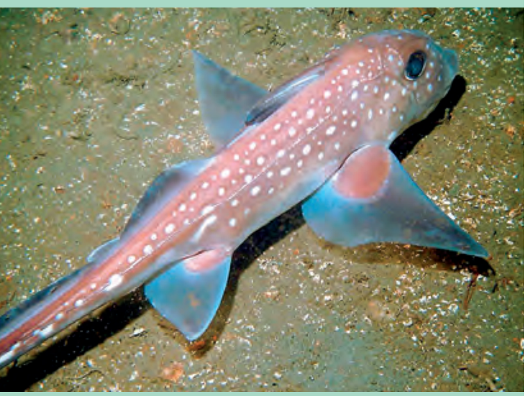
Ancient history of herring presence

A study of 171 coastal archeological sites undertaken by Iain McKechnie and colleagues (2014) found that while modern herring populations can be erratic and exhibit catastrophic declines, the archaeological record indicates a pattern of relatively consistent abundance, providing an example of long-term sustainability and resilience in a species known for its modern variability. The simplest explanation for the discrepancy is industrial harvesting over the last century (McKechnie et al. 2014).

PHOTO: C. FOX

Life at the Bottom of the Sea

Groundfish is the collective name given to all bottom-dwelling fish. Included are the flatfish (halibut, flounder, sole), the rockfish (ex quillbacks, bocaccios), and the greenlings, including lingcod.



Sandy bottoms of the Salish Sea host anemone and brittle star gardens, which foster larger bottom fish such as halibut and flounders and in the deep trenches, large rockfish. In the dark depths, beautiful chimeras (called ratfish for their long tails) explore sandy bottoms.

PHOTO: ELASMODIVER.COM

PHOTO: VANCOUVER AQUARIUM

Groundfish

'Groundfish' describe all types of fish that live near the seafloor. Giants like halibut and lingcod are familiar, yet many lesser-known species are essential components of ocean food webs. In the Salish Sea, the seafloor is expansive and variable, with deep trenches, sandscapes, boulder fields, rocky cliffs and reefs, and silt deposits. Each of these habitats supports a variety of creatures, large and small.

Groundfish are specialized to live near the sea floor, but many specific adaptations exist. Halibut and flounders lie flat along the bottom, exposing only their patterned 'upper side' that blends into the sandy bottom. Sculpins have stiff fins and tend to sit on rocks, hopping more than swimming from rock to rock. Speckled greenlings and lingcod blend into rocky reefs, corals, and sponges. Many of these species are also adapted to live at great depths, with specialized swim bladders that allow them to cope with water pressure.

Groundfish also comprise a major part of the Salish Sea food web—acting as both predators and prey. During juvenile stages when many groundfish live closer to the surface, they become prey for larger creatures including birds, river otters, and other fish. As adults, groundfish will be prey for other fish and marine mammals such as sea lions.

In both Canadian and American waters, groundfish are a commercial and recreational target. In the Salish Sea, they face a variety of threats, but overfishing tops the list (Fisheries 2014c, PFMC 2014). Trawling practices, which drag fishing gear along the sea floor, have also destroyed large areas of habitat throughout their range. In Canada, it was not until several species of groundfish populations began to collapse that an appropriate fisheries management plan was created.

Rockfish

The group of fish we call 'rockfish' comprise many species in the genus *Sebastes*. Around 40 species live in the Salish Sea (Fisheries 2007a, WDFW 2011), some of which congregate in deep trenches (> 40m deep) and others that live closer to shore.

Rockfish transition through several habitats as they slowly mature, typically starting in shallow eelgrass meadows and then moving into kelp forests, then deep rocky reefs or sandy bottoms, sometimes a kilometer below the surface (Palsson et al. 2009). A site on the sea floor can have several rockfish species, with many age classes in each population. The age structure is a key component of a population's resilience.

One of the unique characteristics of rockfish is their extremely slow development. If not caught, many species live to be well above 100. Generation times are slow (quillback, for example is about 30 years COSEWIC 2009) with some species taking 15-25 years to become sexually mature (Meyer, ADF&G). Rockfish give birth to live young. The older they get, the more offspring they produce.

There are three important things to know about rockfish: They are among the longest-lived fish on earth (up to 200 years), they are very vulnerable to over-fishing, and consequently many species are threatened.

PHOTO: T. JACKSON, NOAA

As juveniles, flatfish (e.g. halibut, sole, flounder) are oriented like most fish—vertically. When they are just a few months old, their left eye migrates to the right side of their head. This becomes the topside and the colour on the bottom side fades to white.

PHOTO: NOAA

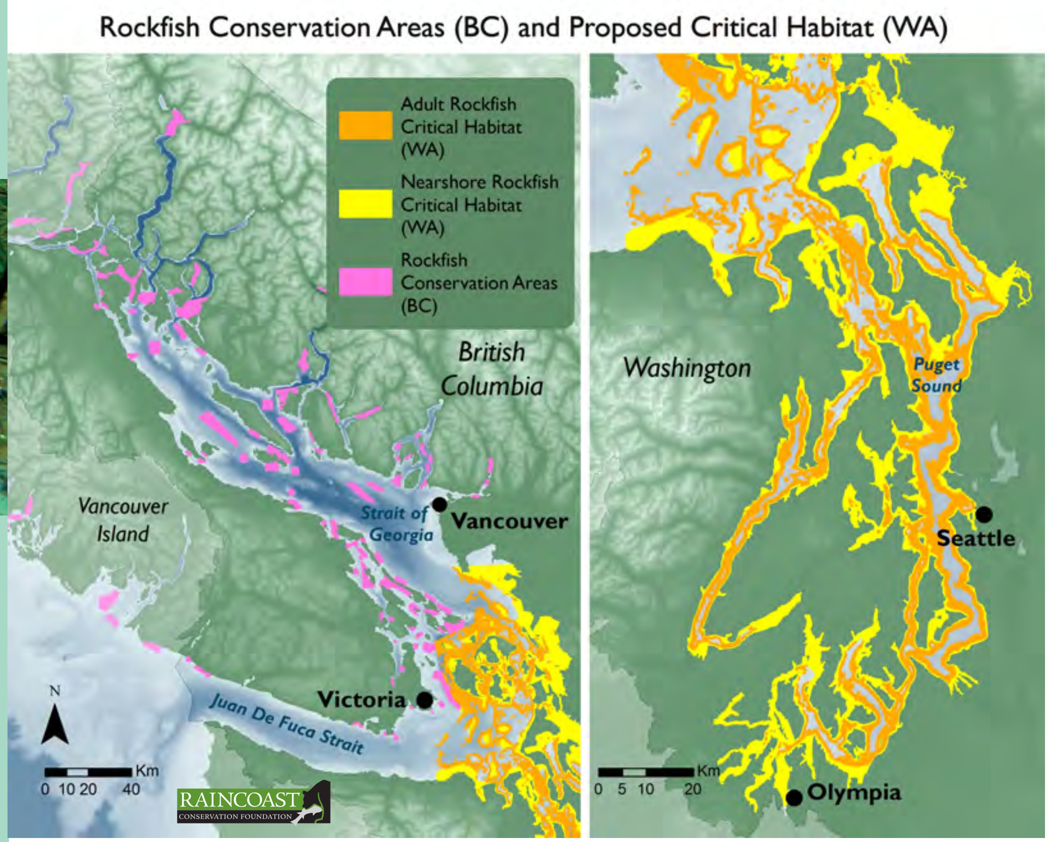


Figure 2.10: Rockfish conservation areas and groundfish distribution and fishing areas in the Salish Sea

A caught rockfish is a dead rockfish.

Rockfish are caught in recreational and commercial fisheries. Their long lives, slow reproduction, and vulnerability to overfishing do not bode well for speedy recovery. Unlike some fish, “catch and release” does not work for rockfish. Their large, gas-filled swim bladder can rupture as they are brought up from depth, which either kills them or prevents them from swimming back down.

A Long Struggle

Given their life history, rockfish do not rebound and recover quickly from population impacts. In Canada and the US, there have been large declines in many rockfish species, largely attributable to fishing practices and harvest rates (Fisheries 2007b, WDFW 2011).

Living at great depths, they are subject to trauma when brought to the surface on fishing lines. Mortality from catch and release is very high, and they are caught as bycatch in nearly all deep-sea fisheries (Yamanaka and Logan 2010). Many species also look similar, leading to potential misidentification and accompanying management difficulties. Other threats include polluted waters near urban areas and derelict fishing gear.

In Washington’s Puget Sound, two species are now listed as threatened under the ESA (canary and yelloweye), and one as endangered (bocaccio). In Canada, three species are listed as threatened under SARA (canary, quillback and yellowmouth), with another five species listed as Special Concern (SARA 2014).

Marine protected areas offer some hope for rockfish. In Puget Sound, Edmond’s Underwater Park is demonstrating that an enforced no-take zone allows rockfish populations to slowly rebuild (McConnell and Dinnel 2002). More ‘no-take’ marine reserves are now being proposed near Puget Sound’s Skagit County.

In BC, reduced fishing in rockfish conservation areas has been implemented in 86 locations in the Salish Sea (Fisheries 2014). BC’s rockfish conservation guidelines, however, are not enforced or legislated by the federal government, and allow mid-water groundfish trawls along with other forms of fishing. Analyses suggest their effectiveness to date has been marginal (Haggarty 2013). Given the long generations of many species and the limited protection they have been afforded so far, recovery will take many decades, assuming that reaching previous levels of abundance is even possible.

Living Dinosaurs: Glass Sponge Reefs of the Salish Sea

Glass sponge reefs were once only known from ancient fossils, believed to have gone extinct sometime in the cretaceous period about 60 million years ago (Leys et al. 2004). But in the 1980s, these 'living fossils' were discovered by researchers studying the depths of BC's Queen Charlotte Sound and Hecate Strait. About a decade later, they were discovered in Georgia Strait and in Howe Sound in 2008.

Formed almost entirely of glass, as the name implies, they are silica-based, stationary animals. Like other sponge reefs, they support an abundance of sea life, and act as refugia and nurseries for threatened rockfish. In fact, young rockfish were found to be five times more abundant on live glass reefs than on nearby dead reefs and off-reef areas (Conway 2005). Glass sponges filter bacteria and debris from the water and return nutrients back into the ocean. To grow, they require extremely stable environments with low sedimentation rates.

Fishing activities, particularly bottom trawling, have seriously harmed these fragile, ancient reefs. In the Salish Sea, more than half of the surveyed reefs have been damaged (Cook et al. 2008). Although some protection has been granted to the northern reefs through trawl closures, the reefs of the Salish Sea have little protection.

Where the Whales Go—Shallow Water Whale Falls.
Whale falls may persist for over 100 years in the deep sea and even longer in shallow-water (Glover et al. 2010). Carcasses of whales and dolphins undoubtedly scatter the floor of the Salish Sea. They offer a glimpse of the greater ecological role these animals play, and the linkages between the top and bottom of the sea.

Whale Falls—A Cascade of Food & Nutrients

When a whales dies, rarely does it wash-up on shore. Most whales sink, whole or in pieces, to the bottom of the sea. In doing so, they create islands of food resources on a typically sparse ocean floor. Sunken whale carcasses are known as 'whale falls'. Whales that die and sink in waters shallower than 200 metres, like the Salish Sea, are less studied than those of deep oceans (Dubilier et al. 2008), but research suggest the process is similar. Carcasses contribute a pulse of fat-rich resources to the ocean floor where a host of organisms—from crabs, snails, fish and sharks—move in to scavenge the body (Dahlgren et al. 2006, Glover et al. 2010). The carcass then succumbs to mats of bacteria (Dahlgren et al. 2006) and decades later, bone-devouring 'zombie worms' finish the decomposition process (Glover et al. 2010).

An Intertidal Trophic Cascade
Raccoons are among the many land animals known to obtain a large portion of their diet from seafood in the intertidal zone. This rich resource however is not infinite, and consumption of intertidal resources—such as crabs and fish—by small predators like raccoons can have a large impact on the abundance of their prey. This is particularly true where top predators (cougars, wolves, and black bears) have been removed by humans and no longer keep small predators in check.
PHOTO: J. SURACI.

More species of sea stars occur in and around the Salish Sea than any other place on the planet (Lamb and Hanby 2005).
PHOTO: J. HEATH

Linking the Land and Sea

The Intertidal Zone

Intertidal zones are the link between the land and the sea. Submerged one hour and dried out the next, an amazing plethora of life has evolved to live between the highs and lows of Pacific tides. With more than 7,000 kilometers of intertidal habitat (Gaydos et al. 2008), the marine shoreline of the Salish Sea is no exception. Whether gently sloping rocky shores, shallow waters or eelgrass beds, a single intertidal site may contain dozens of algae, invertebrate, and fish species, totalling thousands of species throughout the region (Levings et al. 1983, Zacharias and Roff 2001, Lamb and Hanby 2005, Gaydos et al. 2008).

In addition to harbouring a profusion of unique marine life, the intertidal zone is a major, and often vital resource for terrestrial species (Carlton and Hodder 2003, Gaydos and Pearson 2011). Many of the birds and mammals that depend on the Salish Sea derive a large proportion of their diet from the intertidal zone.

Raccoons, mink, otters, and mice are efficient predators that work the low tide into their daily foraging routine. Work by Raincoast scientists shows that raccoons that forage in the intertidal zone can have a strong impact on the abundance of their prey, substantially reducing the numbers of crab and fish around islands where raccoons occur (Suraci et al. 2014).

This highlights the inherent fragility of what seems like plentiful intertidal resources, and the connection that exists among species living at ecosystem boundaries. The diversity and abundance of species on land may depend in a very real way on diversity and abundance of marine communities.

Kelp Forests and other Seaweeds of the Salish Sea

Fringing the light-filled waters of the Salish Sea are the marine algae known as seaweeds. They include the red, green, and brown alga. Like land plants and plankton, seaweeds are photosynthetic organisms that take up light and carbon dioxide from the surrounding environment before releasing oxygen.

Stuck to rocks in pounding surf, undulating in the current at the sea floor and growing in intertidal zones, seaweeds are major contributors to habitats and processes within the Salish Sea.

Among the most conspicuous seaweeds are the kelps, many of which form forests that host a myriad of species. Kelp forests are one of the most productive, diverse, and dynamic ecosystems on the planet (Mann 1973). They support all forms of animal life including invertebrates, fish, sea otters, corals, sponges, and even marine birds.

Compared with land plants, kelps have no roots to take up nutrients (just a holdfast to anchor them), they produce sugars instead of starch, and often form air bladders to help them float

PHOTO: J. HILDERING.

The structure, biomass, and diversity of organisms that live in kelp forests combine to have a profound influence on the surrounding ocean. They dampen wave action, alter currents, influence erosion rates, and reduce light (Steneck et al. 2002). They provide a substrate for non-mobile marine life, and shelter, habitat, and nursery grounds for young fishes, including salmon, rockfish, and herring.

Prone to disturbance by storms, changing temperatures and being eaten (namely by urchins), kelp forests can be short lived (Steneck et al. 2002). Entire forests can disappear within days or months but, just as importantly, they and their entourage can return and rapidly regenerate (Tegner et al. 1997; Steneck et al. 2002). In locations like the Salish Sea, grazing by urchins is considered the most common and important agent of kelp deforestation (Steneck et al. 2002).

In the Salish Sea, bull kelp are the main species that creates the canopies of kelp forests. These forests offer shelter, protection, and food resources to marine life, in the form of nutrients, detritus, and animals that graze on kelp directly (Steneck et al. 2002).

PHOTO: J. HILDERING

Eelgrass

Eelgrass is a flowering plant adapted to life in shallow marine waters. It roots in sand or mud where waves and currents are not too severe. Like kelp, eelgrass needs light to grow and reproduce, so it is typically found in less than 10 metres of water (Mumford 2007).

The plants also hosts dozens, if not hundreds of other species of algae and plankton, which also contribute to food webs for young salmon, herring, and groundfish (Wright et al. 2012, Phillips 1984, Olyarnik 2006).

For young salmon, the use of eelgrass can increase survival (Semmens 2008) and the loss of eelgrass has been implicated in local salmon declines (Bravender et al. 1999). Eelgrass beds are equally important to Pacific herring, where they are used as substrate for spawning (Penttila 2007) and then rearing grounds for the larvae and juveniles (Olyarnik 2006). Equally, the loss of eelgrass communities can contribute to declines in fish populations, and so on up the food web to reach birds and mammals.

Attempts to determine eelgrass baselines in the Salish Sea are challenging, but the loss of meadows from known locations is documented and driving the need for proper assessments (Dowty et al. 2006, Mumford 2007, Wright et al. 2012). In the last two decades, such assessments have shown more losses than gains in Puget Sound (Mumford et al. 2007), with a significant proportion of shorelines no longer in their natural condition (Pentilla 2007).

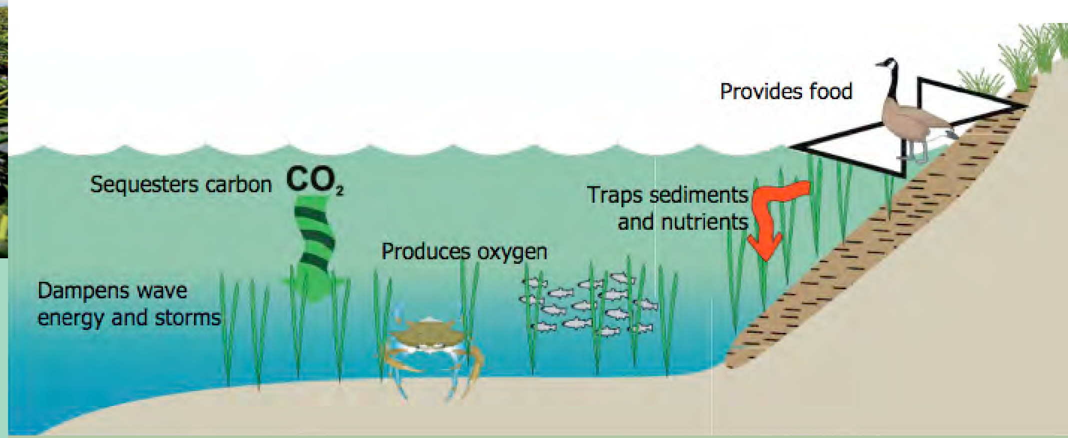
In BC, 70% of the Fraser River estuary wetlands (which are not exclusive to eel grass) have been diked, drained, and filled to reclaim land for development. Similarly, on Vancouver Island, about half the Nanaimo and Cowichan estuary wetlands have been lost (BC CDC 2006).

Port and berth construction, dredging, overwater structures likes docks and marinas, and shoreline armouring all degrade and eliminate eelgrass. The beds are also sensitive to contamination from chemicals, oil, fertilizers, and pesticides from gardens and agriculture, decreased light, and sediments.

The loss of eelgrass beds is a growing concern, both in the Salish Sea and around the world (Orth et al. 2006). Environment Canada states an average global decline of 7% per year since 1990. Although not restricted to eelgrass, an estimated 18% of coastal marine and nearshore wildlife habitat in the Salish Sea had been destroyed by 1994 (Wright et al. 2012).

In the Salish Sea, the Fraser Estuary including Robert's Bank and Boundary Bay, support one of the most extensive and contiguous eelgrass communities on the Pacific coast. Many other areas throughout the Salish Sea also support critical eelgrass habitat.

PHOTO: D. AYERS, USGS.



Eelgrass meadows are highly productive ecosystems. After fixing carbon and developing blades that can grow to more than a metre. Eelgrass beds slow and filter water, stabilize bottom sediments, dampen waves and trap sediment, detritus, and larvae (Mumford 2007). The carbon from the plant also makes its way to food webs that supply nutrients to finfish, shellfish, marine birds, and dozens of insect, bug and small invertebrate species (Wright 2012, Mumford 2007).

Marine Exchanges

The annual return of spawning salmon is the most notable example of marine resources providing important food and nutrients to forest dwellers. Salmon often arrive at a critical time for the mammals, birds, amphibians, and insects that benefit from their arrival (Hocking and Reynolds 2011, Field and Reynolds 2011, Darimont et al. 2009).

Work by Raincoast scientists has shown a similar benefit comes from spawning Pacific herring (Fox 2013, Fox et al. 2014). Black bears may consume substantial quantities of herring eggs in addition to consuming sand hoppers (beach invertebrates) that have eaten herring eggs in the spring, providing them with an important fat-rich food source. Other species, including gray wolves and songbirds, also emerge from the forest in spring to feast on spawned herring eggs.

Some seabirds, including gulls and oystercatchers, derive a huge portion of their diet from the intertidal seafood feast, and even small songbirds, like the song sparrow, can be found foraging on tiny crustaceans along shorelines in the Salish Sea.

While the salmon and herring subsidy can be observed in the rivers and shorelines, less iconic marine species—like crabs, small intertidal fish, clams, and worms—are also critical food sources for many land-dwelling birds and mammals.

PHOTO: A. PAUL, WIKIPEDIA

Trophic Cascades: Ecological Chain Reactions

Top-down trophic cascades occur when predators in a food web suppress the abundance and/or change the behavior of their prey, thereby influencing predation in a lower trophic level. This chain reaction can result in dramatic changes within food webs, including to nutrient cycling. In marine ecosystems, the disappearance of kelp forests is an example of a top down trophic cascade. For more than a century, the absence of sea otters from the Pacific coast allowed urchins to devastate entire kelp forests. When sea otters were present, they preyed on urchins, which controlled the number of urchins and their excessive grazing of kelp. Without sea otters, there were no constraints on urchins, and a series of ecological chain reactions was initiated.

The reintroduction, and subsequent reoccurrence, of the sea otter is bringing this species back to the coast. At present, sea otters have re-occupied small areas of the Salish Sea, primarily along western side of the Strait of Juan de Fuca and the Olympic Peninsula. Isolated sightings have also occurred elsewhere (see Fig. 2.1).

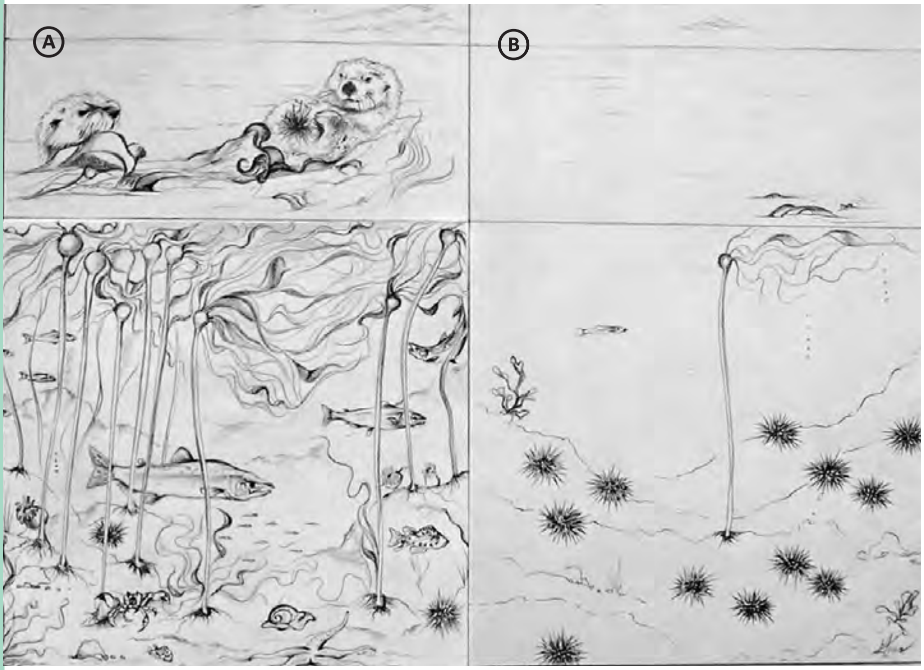


Figure 2.11 A simplified example of trophic cascade interactions. **A)** In the presence of sea otters, kelp forests flourish providing habitat to young fish and other species. **B)** In the absence of sea otters, kelp forests become overgrazed by urchins and no longer support fish and other species that depend on kelp habitats.

GRAPHICS: MAYA KAMO/RAINCOAST

Estuaries and the Fraser River Delta

At the mouth of the Fraser River lies one of the most productive and diverse estuaries on the Pacific coast. Its ecological connections extend thousands of kilometres into the Pacific Ocean through the movements of migratory birds, mammals, and fish, especially salmon. The foundations for these remarkable pathways are the river delta's tidal mudflats, marshes, sloughs, flooded fields, eelgrass beds, shorelines, and forests.

The Fraser delta is the rearing ground for some of the world's largest salmon runs. As such, millions of juvenile salmon rely on this estuary for food, shelter, and protection. Fraser River salmon are grouped not just by species, but also into populations that reflect their unique traits and adaptations to local streams and rivers.

Populations such as river-type sockeye, ocean-type Chinook, nomadic coho fry, and chum salmon rely heavily on the sloughs, marshes, and estuary habitats of the delta. These young salmon can spend months feeding, growing and preparing for their ocean journey. Because large tracts of the estuary and shoreline have already been paved and developed (causing extensive loss of salmon and habitat), remaining sections in the delta are irreplaceable.

Juvenile salmon experience the highest growth rates of their lives while in estuaries and nearshore waters. Eelgrass beds are the foraging grounds for dozens of resident and migratory waterfowl.

PHOTO: NOAA.

Land-dwelling mammals that earn their living, or part of it, from the sea are considered maritime mammals. In the Salish Sea, this includes bears, wolves, mink, river otters, cougar, and even black-tailed deer, which rely on intertidal grasses in winter when other foods are scarce (Peterson 2001).

PHOTO: N. DEBRUYN

Other estuaries once existed throughout Vancouver Harbour and Burrard Inlet. The contribution and function of these areas has been significantly reduced due to extensive human modifications that have destroyed foreshore and intertidal habitat, armoured shorelines, and impaired water quality. Unfortunately, these ongoing activities threaten the remaining habitat within the delta.

PHOTO: I. HINKLE

Estuaries, saltmarsh, eelgrass, and kelp communities are the shallow shoreline habitats that provide food, shelter, and protection to juvenile salmon, herring, lingcod, and flatfish, as well as vital migration corridors for young salmon.

The US federal government has defined these shoreline habitats to be Essential Fish Habitat under the Magnuson–Stevens Act. In coastal marine waters, US definitions mean that every estuary, river mouth, slough, bay, foreshore, and extended shoreline in the Salish Sea is Essential Fish Habitat for salmon.

Although still falling short of adequate protection, the designation underscores the importance of these habitats to wild salmon and other fish species. Eelgrass and kelp beds are further identified as Valued Ecosystem Components by the Puget Sound Nearshore Partnership.

The Human Footprint

Unfortunately, coastal ecosystems have fallen victim to a wide range of human impacts (Foley et al. 2010). Urban development and alteration to the shorelines of the Salish Sea has increased extensively in the past several decades, leading to direct habitat loss (Levings and Thom 1994) and toxic contamination (Gaydos et al. 2008).

In marine waters, habitat can be degraded and fragmented similar to terrestrial landscapes. Acoustic disturbance from vessels and shoreline construction can affect larval fish, adult fish (Slabbekoorn et al. 2010) and marine mammals (Wartzok et al. 2003). Boat propellers can kill copepods, a dominant zooplankton, leaving zones of reduced food abundance (Bickel et al. 2011). Logging activities can release pollutants, raze large sections of shoreline with log-booms and prevent the re-settlement of bottom dwelling organisms (McDaniel 1973). Dock and over-water structures break up mammal access to shorelines. These are a few examples of how human intrusion can create zones of lost or degraded habitat that serves to fragment larger areas.

Another pervasive human impact on Salish Sea intertidal communities is that of introduced species. As many as 90 alien species have been introduced to BC's coastal waters, many of which came as hitchhikers with species introduced for aquaculture (Dudas 2005). The Pacific oyster, the green crab (Dudas 2005), and the seaweed *Sargassum muticum* (Britton-Simmons 2004) have significantly altered intertidal communities by eating or outcompeting native species.

One of the ocean's primary roles is the regulation of the Earth's climate. As carbon dioxide emissions have increased in the last century, the oceans have picked up the slack, absorbing excess CO_2 from the atmosphere and dissolving it into seawater (NOAA 2015).

Although this uptake has mitigated the effects of climate change, the carbon-based molecules formed in this process produce carbonic acid, lowering the ocean's pH and raising its acidity. Plankton, corals, and other invertebrates that have shells or plates made from calcium carbonate, are corroded by carbonic acid. As these animals form the basis of the food web, threats to their populations can reverberate through marine ecosystems and into our economy and food supply.

Independent of the threat that oil tankers pose to the region, the rapidly growing human population has put considerable pressure on coastal waters and habitats. To date, the loss of eelgrass, deltas, foreshores, and natural shorelines is due almost exclusively to human activities. The region's population is forecasted to exceed 9,000,000 people by 2020 (PSGBEIR 2006). From headwaters to deep waters, extensive efforts must be taken now if remaining intertidal, foreshore, and marine habitats of the Salish Sea are to be protected. Critical habitat loss, with a ripple effect through fish, bird, and mammal populations, will accompany this unless countered now.

Restoration of the Salmon Creek mill site in Puget Sound is restoring estuary habitat for steelhead, chum, and Chinook salmon, as well as for shorebirds, shellfish, waterfowl, and even Roosevelt elk.

PHOTO: NOAA

Global climate change and the associated temperature increases have reduced the range of some organisms and expanded that of others. Locally, intertidal organisms like mussels—which provide essential habitat to a variety of other species—have reduced their intertidal range (Harley 2011).

Three Salish Sea invertebrate species are listed as conservation concerns in either Canada, the US or both (Gaydos and Brown 2011). All three (Newcombe's periwinkle snail, the Olympic oyster, and the northern abalone) have fallen victim to habitat loss, competition with invasive species, pollution, and overharvesting.

PHOTO: NORTHERN ABALONE–DFO